SHELF-SLOPE STABILITY ASSESSMENT FROM
MULTIRESOLUTION (WAVELET) ESTIMATION OF SLOPE AND CURVATURE FROM GRIDDED BATHYMETRY DATA

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LONG-TERM GOALS

The overall goal of this study is to assess slope stability in the East and West Coast STRATAFORM study areas of the U.S. continental margin. Maps of mass-wasting hazard potential maps for the STRATAFORM areas will constitute an end-product of this study.

OBJECTIVES

Because slope stability assessment is generally based on local bathymetric slope gradient (and curvature) criteria we need to understand the effects of (1) the finite resolution of gridded bathymetric data sets, and of (2) noise, error, and artifacts in those data, on the accuracy with which local slope and curvature can be determined. Two related objectives are sought in this context: i) Determination of the length scaling properties of bathymetry and topography, because estimates of slope gradient and curvature will converge or diverge with increasing resolution (i.e. at smaller scales) dependent on the scaling behavior of topography or bathymetry. ii) Amelioration of swath-parallel errors and artifacts in gridded bathymetry, so that assessment of slope stability can be made at the highest possible resolution in the STRATAFORM test areas.

APPROACH

Wavelet transform-based methods provide the best way to achieve both objectives. The length scaling properties are found by taking the wavelet transform of gridded bathymetry (or topography) using two-dimensional wavelets that are successively higher derivatives of a radially-symmetric Gaussian smoothing function. As we progress from lower- to higher-order derivative wavelets, scaling exponents determined from the slope of log-log plots of wavelet transform amplitude versus wavelet dilation tend to a constant value. This constant value is the true or wavelet independent scaling exponent of the bathymetry or topography. Amelioration of the swath-edge artifacts in gridded bathymetry is conducted by decomposing

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the gridded bathymetry in terms of wavelet elements that are locally optimal in terms of position, orientation, phase, and scale properties. This algorithm quickly and efficiently removes the coherent structure in signals leaving a residue of a random noise nature. Because the signal decomposition conserves energy, the unwanted swath-parallel artifact components (whose orientations and scales are known a priori) can be penalized during signal reconstruction.

WORK COMPLETED

We have completed a manuscript dealing with the section of the study primarily concerned with the scaling properties of topography (Stark and Weissel, submitted). Earlier results from that work were reported at the Fall 1996 meeting of the American Geophysical Union. Work is continuing on the development of algorithms for the amelioration of swath-edge artifacts in gridded bathymetry. Preliminary results will be presented at the Fall 1997 meeting of the AGU.

RESULTS

A new understanding of the scaling properties of topography came from wavelet analysis of seven 40m gridded DEMs over the western Southern Alps of New Zealand (Fig. 1). Here, wavelets that are the first six derivatives of the Gaussian smoothing function were used. The main results are that (1) topography is more regular, i.e. ``smoother'', than previously thought from earlier studies which employed different techniques, and (2) the true global scaling exponent is only obtained if wavelets of sufficiently high order (here, –2) are used in the analysis (Fig. 1).

IMPACT/APPLICATIONS

Our work seeks to reduce the effects of swath-parallel artifacts in gridded bathymetry data that arise because of inadequate seawater refraction corrections for swath outer beams. This problem will be general one in shallow water areas of the continental shelves and slopes exhibiting large temporal variability in the water column. The methodology developed for artifact reduction in the STRATAFORM test areas is expected to be generally applicable elsewhere.

TRANSITIONS

The work on artifact amelioration in gridded bathymetry is an application (in part) of earlier work supported by ONR at New York University under grant # N00014-91-J-1967 , in effect adding value to that previous ONR investment. Colin Stark and I are considering publishing a monograph with an accompanying CD-ROM containing all our wavelet transform development work, including detailed applications, software and manual, and case study examples. If we decide to go ahead, that publication should be in the publisher's hands by the end of 1998.

RELATED PROJECTS

Our results will assist other scientists whose projects address slope stability problems in the STRATAFORM test areas. In particular, we are coordinating our effort with that of Homa Lee and colleagues of the USGS, who undertook a suite of geotechnical measurements on sediment samples from the offshore Eel River survey area in order to better understand the mechanical stability of shelf and upper slope sediments.

REFERENCES

Stark, C.P., and J.K. Weissel, Using wavelets to determine slope stability from Digital Elevation Models (DEMs), 1996 AGU Spring Meeting Abstract Volume, S264, 1996. Stark, C.P., and J.K. Weissel, Analyzing topography using wavelet transforms, J. Geophys. Res., submitted.
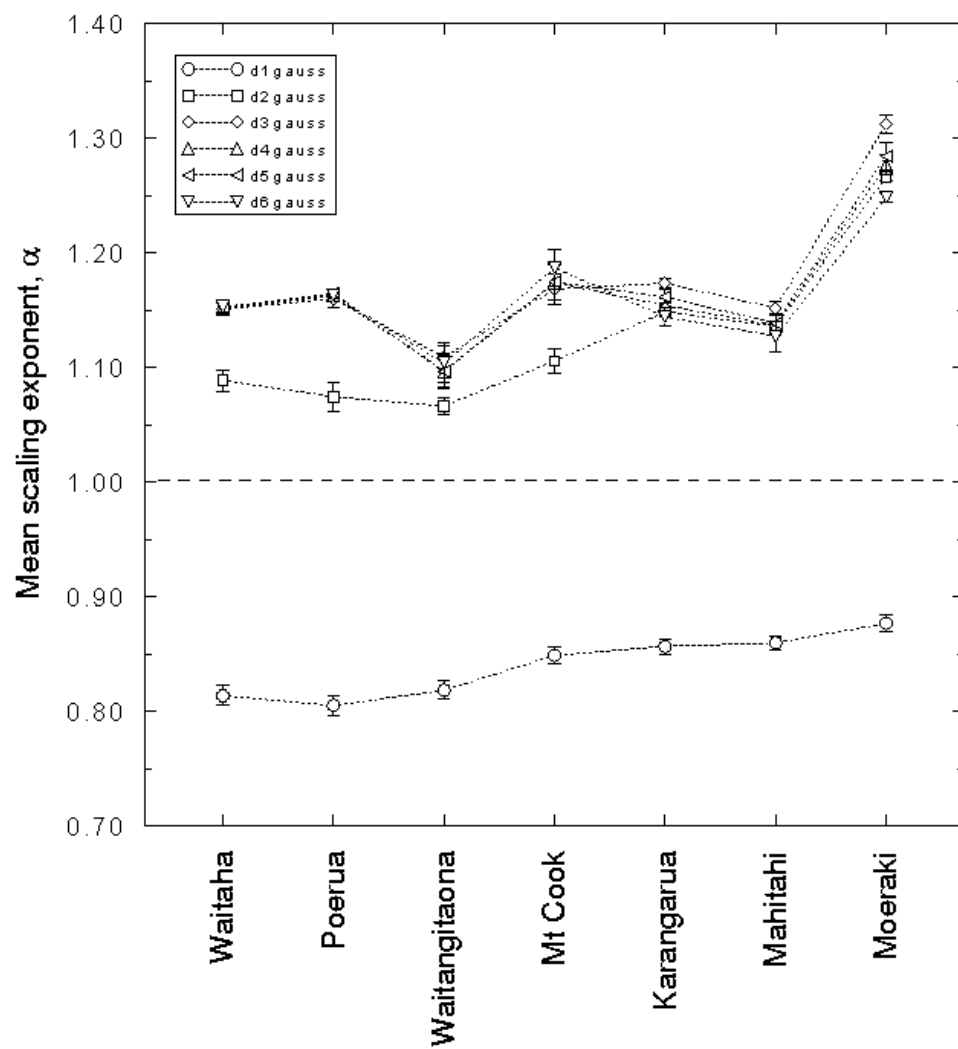
Fig. 1: Mean local scaling exponents for seven 40m DEMs from New Zealand.